CHANGES IN BODY WEIGHT OF AMERICAN GOLDFINCHES

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Various authors (e.g., Baldwin and Kendeigh 1938:416; Fisher 1955:59; Perrins 1964:883) have commented that body weights of wild species of birds have not received adequate attention. Though seldom published, vast amounts of weight data have been collected in typical banding projects. As a result of my activities, I have accumulated weight and measurement data from banding 1567 American Goldfinches (*Spinus tristis*). To make these available, I present here an analysis of seasonal and sexual variation in body weight and simple comparisons of wing chord and body weight.

METHODS

These data were taken from a general banding program conducted for 5 years at the Cincinnati Nature Center, 25 km east of Cincinnati, Ohio. All birds were taken nonselectively by traps and nets. No birds were held captive or collected, and no experiments were done, so the bias created by trapping was thus held to a minimum. While not of prime interest at the time of banding, the goldfinches constituted over 15% of the bandings at the Nature Center.

Birds were captured on Sundays and Mondays throughout the year except the last half of December, from March 1967 through July 1972. Each day, unless it was raining, the traps were opened at dawn and operated as long as birds were being captured. As a rule, on Sunday large numbers were trapped in the morning, then fewer in the afternoon, partially because of the banding activities. The morning of the second day was less fruitful and the afternoon captures were practically nil. The traps were used as feeding stations daily throughout the year, baited with sunflower seeds and grain mixtures or chicken scratch feed. Traps were operated at all seasons of the year; nets were used irregularly and only when the traps were not effectively attracting birds, particularly in warmer weather and when natural foods were abundant.

Six McCamey Chickadee traps, set 2 per tray on 3 elevated trays; one 6-cell Potter trap on the ground; and one 1 m $\times$ 2 m $\times$ 0.6 m all-purpose or figure-eight trap were used. These were placed within 20 m of and visible from a central permanent banding office. When needed, from one to seven 12 m, 30 mm mesh nets were set in an adjoining field planted with wildlife crops such as millet, sorghum, corn, sunflower, etc., and perennial plants yielding fruit or berries.

The time a bird was in captivity was held to a minimum. Generally, birds were collected at intervals of 10 to 15 min, placed into isolated chambers of a darkened box, and immediately taken to the office and processed. If a particularly large number of birds was captured, all traps and nets were closed until all captured birds were released. Birds were seldom in captivity for as long as 30 min.

Standard procedures in the office were to remove a bird from a box; determine the species, sex, and age; affix a U.S. Fish and Wildlife Service band; measure the wing chord and tail; determine the fat class; check for molt, breeding condition, abnormalities, injuries, etc.; and finally weigh and release the bird. The birds were weighed to the nearest 0.1 g in an upright paper cone on an Ohaus triple-beam balance. The balance was occasionally checked for accuracy using standardized weights. I did all the processing, so no variations have resulted from different operators. My wife helped to remove birds from traps and nets, recorded all field information, transferred data to the individual bird's record card, and made these cards available at subsequent recaptures.

Sex of goldfinches was determined by plumage characteristics. Winter males were determined by their glossy black remiges and rectrices; on winter females these feathers were dull to brownish black. A few intermediates, usually young birds, were recorded as sex unknown and were excluded from the study unless later recapture established the sex.

Age was recorded and is presented here in the terminology of the U.S. Fish and Wildlife Service Bird Banding Laboratory as follows: HY (Hatching Year) = from hatching to the end of their first calendar year; SY (Second Year) = birds in their entire second calendar year; AHY (After Hatching Year) = a catchall class but for male goldfinches may be considered as after second year birds.

Age was determined by the following characteristics (see Olyphant 1972, Forbush 1929): *HY males.*—Skull pneumatization is not completed until end of year. Plumage is fresh in August–September. Juvenal lesser wing coverts are olive greenish-yellow; juvenal wingbars are buffy, fading to off-white, are narrow and become worn during second year. Fall molt replaces only head and body plumage. *SY males.*—Skull is fully pneumatized. Plumage is worn in August–September. Juvenal lesser wing coverts are as above. Juvenal wingbars are badly worn or absent. Fall molt is complete and lesser wing coverts and wingbars of an AHY male are attained in October–November of second year. See discussion below. *AHY males.*—Like SY males except lesser wing coverts are bright yellow and wingbars are broad and white. *HY females.*—Skull pneumatization is not completed until end of year. No standards were known to distinguish them after pneumatization is completed. *AHY females.*—Skull is fully pneumatized, see above.

I believe these characteristics permitted approximately 90% of the males to be aged correctly, but a few individuals are known to have failed to develop the bright yellow coverts even after reaching their third calendar year. A method of aging females published by Olyphant (1972) had been attempted, but some variations were noted so the procedure was abandoned before checking thoroughly.

Measurements were made of the unflattened chord from the bend of the wing to the tip of the longest primary with a rule under the folded wing (Wiseman 1970). The longest rectrix was measured by inserting a plastic rule between the central pair of rectrices, against the base of the tail.

Fat stores were subjectively recorded as fat classes 0–3: fat class 0 = none to trace amounts; fat class 1 = moderate amounts in the furculum, but not sufficient on the abdomen to fully conceal the externally observable viscera; class 2 = furculum filled to level with the clavicles, the abdomen with a layer concealing the viscera; class 3 = furculum bulging convexly, the abdomen distended with a layer of fat.

Weather data were taken from official reports of the U.S. Weather Bureau station at Greater Cincinnati Airport, about 30 km WSW of the Nature Center.

Calculations.—Basic statistics of these data were calculated using an IBM 765/360 computer at the University of Cincinnati. Because of the many small samples involved, "N-1" was substituted for "N" in the formulae for calculating both the standard deviation (S.D.) and the standard error of the mean (S.E.), and these formulae were used throughout the study. Means ± 2 S.E. were used to measure probability at the 95% level. Regardless of how meager a sample was, it was plotted into the charts if ± 2 S.E. remained within the range of the sample.

If a bird was captured more than once on the same day, only the initial capture data were used for that day. When birds were taken on consecutive days, both weights were included in the study (see discussion below). One bird, an HY male weighing 9.3 g in October, was so far below the other male weights it was considered abnormal and was excluded. Any birds found to have missing or broken remiges and/or rectrices, and all birds molting these feathers in the fall were excluded from analysis of wing and tail measurements. The effects of netting versus trapping of birds was considered negligible, so these groups were pooled. Throughout the analysis, the sexes were treated as distinct populations.

For anyone wishing more details, the data have been keypunched and are available on request.

RESULTS AND DISCUSSION

Capture rates and samples.—The numbers of male goldfinches captured were always larger than the numbers of females (no field observations were made of the sex ratio). The aggressive nature of the males may have contributed slightly to their higher capture rate.

Table 1 lists the dates (by month) of 1448 captures of 978 individual males and 756 captures of 538 females. Of these, 726 males were captured only once, 148 were captured twice, 56 were taken 3 times, and 47 males were taken 4 to 10 times. One male (#107–31428) provided 19 useful weights from 1968 until last seen on 5 April 1971. Of the females, 413 were captured once, 78 twice, 25 three times, and 21 were taken 4 to 6 times. One female (#116–37283) provided 12 adult weights between 1 September 1969 and 9 April 1972.

Generally, from January through April the goldfinches were trapped, whereas in the remainder of the year they were netted. At the start of the program, very few were trapped. Beginning in February 1970, for unknown reasons, large numbers of goldfinches came and were trapped in both ground level and elevated traps. They disappeared from our trapping area at the end of April, about the time natural foods became abundant. The number of goldfinches netted was influenced by a variety of conditions, including: rate of growth and yield of food crops, sufficient height of plants to conceal the nets, and the abundance of all birds in the field. At times, all nets had to be closed in order to process the large number of netted birds and, occasionally, some birds were released without processing.

On some mornings as many as 125 to 150 birds were processed during the first 5 or 6 hours. In these instances, birds that had been previously

TABLE 1

DISTRIBUTION OF CAPTURES BY MONTHS AND YEARS FOR 978 MALE AND 538 FEMALE GOLDFINCHES

MONTH		1967	1968	1969	1970	1971	1972	Totals
JAN	M	N*	0	0	3	35	33	71
	F	N	0	0	0	15	12	27
FEB	M	N	0	0	151	N	44	195
	F	N	0	0	64	N	28	92
MAR	M	0**	0	2	160	26**	97	285
	F	0**	0	1	85	12**	54	152
APR	M	1	0	0	68	266	103	438
	F	1	0	0	39	106	48	194
MAY	M	9	0	8	0	11	4	32
	F	7	0	3	0	8	8	26
JUN	M	27	3	5	2	1	0	38
	F	9	3	8	0	1	0	21
JUL	M	5	4	30	1	11	N	51
	F	6	2	21	5	2	N	36
AUG	M	3	48	41	18	5	N	115
	F	2	29	10	3	1	N	45
SEP	M	19	68	16	31	2	N	136
	F	23	43	12	31	1	N	110
OCT	M	53	0	6	6	0	N	65
	F	35	1	4	4	0	N	44
NOV	M	5	2	11	2	0	N	20
	F	0	0	6	0	0	N	6
DEC**	M	0	0	0	2	0	N	2
	F	0	0	0	3	0	N	3
TOTALS	M	122	125	119	444	357	281	1448
	F	83	78	65	234	146	150	756

* N = not operating; ** = partial operation with number of captures for shortened period.

banded were merely examined and weighed, resulting in incomplete measurement records.

Migration.—I found no evidence of migration either by a pre-migratory build-up of fat or by recoveries of birds elsewhere. Over a dozen individuals, including both sexes, were captured in both summer and winter, indicating that some birds may be residents.

Monthly weight variations.—Each sex shows an inverse correlation of weight with ambient temperature (Fig. 1) as has been shown with other species (e.g., Baldwin and Kendeigh 1938, Odum 1949, Helms and Drury

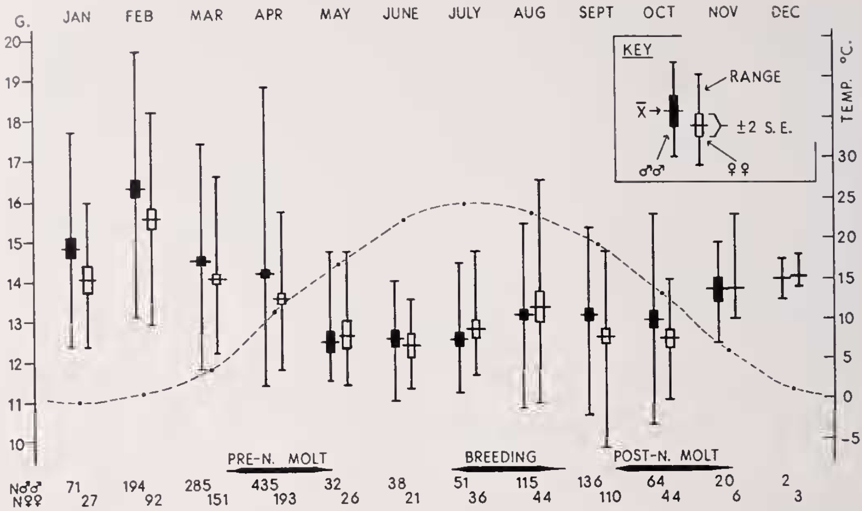

FIG. 1. Annual cycle of body weights of American Goldfinches, all years and all age groups of each sex combined. N = sample size. Ambient temperatures are monthly means (dots) connected by dashed line.

1960). The lowest temperatures (mean 0°C) were in January, but the mean body weight of each sex peaked in February (mean temperature 1°C), a lag similar to that noted by Odum (1949). By March the temperature had risen (mean 4°C) and the mean body weight had started to drop. This drop continued into summer, but in both sexes the rate of drop was much less from March to April than from April to May. This difference in rate of weight decrease may be related to the molt in April. King et al. (1965:244) found an increase in non-fat body weight correlated with the molts of White-crowned Sparrows (*Zonotrichia leucophrys*) and suggested that, "Although the components of this variation have not been investigated, it seems probable that follicular enlargement, growth of papillae, and variations in blood volume must contribute the major fractions."

Through the winter, female goldfinches averaged about 0.5 to 0.9 g lighter than the males, but May females were about 0.2 g heavier. The female begins and ends the prenuptial molt about 10 days later than does the male. Although the males had completed the molt in April, the females were still molting in early May and had a heavier mean body weight. In June, females were again lighter than males and both were at their lowest mean weights of the year.

In July, as temperature peaked (mean 25°C), female goldfinches showed an increase in mean weight not found in males. My field notes as well as

Mundinger (1972) indicate the incubation patch was developing at that time. In August, both sexes reached their maximum mean weight of the summer. King et al. (1965) found that in female White-crowned Sparrows the maximum body weight in summer accompanied the period of maximum oogensis. The goldfinch nests in August locally, and the increase in weight in both sexes seems correlated with breeding.

In September, males remained at a high mean weight, whereas females dropped in weight. King et al. (1965) reported a similar drop in weight in White-crowned Sparrows which they related with either the greater attentiveness to the young by the female, the partial involution of the reproductive organs, or possibly a combination of these. The newly fledged young are included in the September samples along with the adults who were caring for them. The effects on the mean weights exerted by the young will be detailed later.

By October most adults had dispersed, becoming secretive during their postnuptial molt. The young, on their own while undergoing their partial (body feathers only) postjuvenal molt, remained in loose flocks and were captured in fair numbers. When compared with the September mean weights (see Fig. 4) for respective age groups, the October samples showed 58 HY males lost an average of 0.1 g, 35 HY females gained 0.2 g, 6 AHY males gained over 1 g, and 9 AHY females lost about 0.6 g. Relatively more males than females were in molt in October. Though not statistically significant, these changes suggest that more work and larger samples at this period of the year would confirm the trend.

The November and December samples, though small, tend to indicate a gradual increase in weight toward the higher winter levels. In November, the females (5 HY and 1 AHY) were all in molt, whereas 8 of the males were AHY birds and some of these had completed their molt.

Variations in wing chord and tail measurements.—Mean female wing and tail measurements (Fig. 2) in all months were significantly shorter (about 2.5 to 3.0 mm on the wing chord and about 1.4 to 2.0 mm on the tail) than the mean measurements of males, but the ranges of measurements of the sexes overlapped considerably throughout the year. Changes in feather length, obviously due to wear, continued throughout the year until the fall molt. The degree of wing and tail wear was about the same for the sexes, but was more severe on the tail. The combined November and December samples indicate the increase expected after the adult molt. The variation in size and age, as well as wing chord to weight relationship, will be detailed later.

Basic mean body weight and rate of increase.—For later comparisons, I decided to determine the basic mean body weight for each sex: the

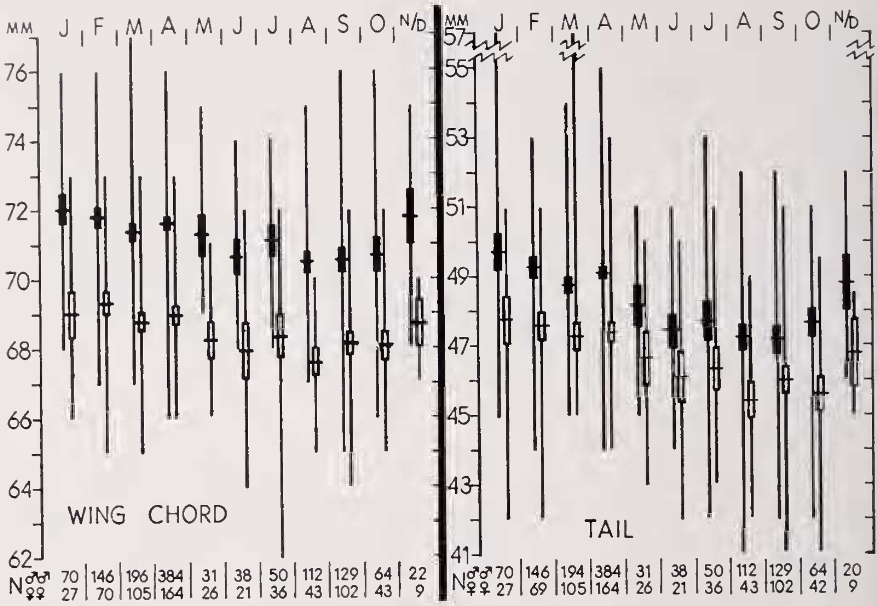

Fig. 2. Annual cycle of wing chord and tail measurements. All years and all age groups of each sex combined. Conventions as in Fig. 1.

lowest weight of the year when the body contained a minimum of fat. I also wanted to know the hourly rate and/or percentage of increase in weight occuring in one day when the weight was at this basic level. The basic weights included the food present in the body, of course, because food is a vital part of the hourly and daily variations in weight which occur naturally in all animals. I was not determining a "fat-free" weight as have others (e.g., Connell et al. 1960, King et al. 1965, Odum et al. 1961) who extracted the total lipids from a dead body by chemical means; my birds were alive and active

In June, both sexes were at their lowest mean weights. but the samples were too small to permit the computation of an hourly rate of change. Noting the males in May, June, and July had essentially the same mean weights, range, and S.E., I combined these months to form a sample of 121 males with a mean weight of 12.5 g. When the age groups were tested, the variation was only 0.1 g. The combined sample was then separated by hours and a mean weight calculated for each hourly period (Fig. 3). A linear regression computed from the hourly means showed an increase of slightly less than 0.05 g per hour for an increase of about 4% for the day. When the same procedure was applied to the female weights for

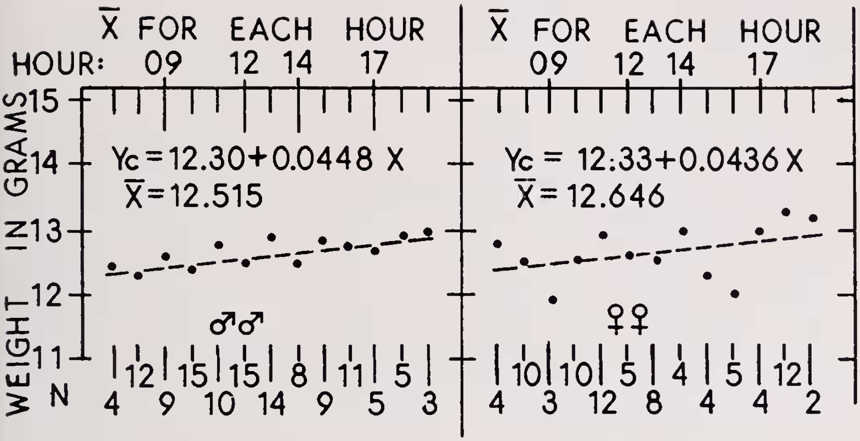

FIG. 3. Means of diurnal weights (dots) by hour of capture during May–July (data pooled) with regression line calculated from means. Conventions as in Fig. 1.

those 3 months, the combined sample indicated the females were the heavier sex which is not true for most of the year. Therefore, the mean weight was discarded; instead I used the June mean weight of 12.4 g. The linear regression showed a rate of increase essentially the same as for males, and as this seemed normal, it was retained. The reason the mean weight of females, as determined in Fig. 3 is high, is due at least in part to molt of females in May as discussed above and the start of gonadal activity in July, which will be discussed later.

Finally, after preliminary testing of these figures, I used basic mean weights of 12.5 g for males and 12.4 g for females and 4% as the rate of increase for one day for both sexes in comparisons with other periods.

Variations in weight during the breeding season.—During July, the incubation patch was developing and the mean weight of females increased 3.3% above the basic (June) mean weight. In August, most females had a well formed, vascular incubation patch and some occasionally showed abdominal distention which I associated with a mature egg about to be laid. Holcomb (1969) reported a mean date for clutch completion of late July for goldfinches in northern Ohio. While I have not recorded nest dates, breeding conditions observed on banded females indicated eggs were laid in late July and in August. Two females (#107–31198 and 31200) were taken on 18 August 1968 at 18:45 weighing 16.5 g and 16.1 g; as their abdomens were swollen, it seemed they were ready to lay eggs. A third female (#107–31201) was taken the same day at 19:30 weighing only 13.2 g; as she had a good brood patch, I concluded she had com-

FIG. 4. Wing chord, tail measurements, and weights of individual age groups from September, all years combined. Conventions as in Fig. 1.

pleted her clutch. The heavier females were up to 33% above the basic mean weight, and the total August sample of females (13.3 g) was 7.3% above the June mean. One female, banded as an HY in September 1967 weighing 12.4 g, was taken 25 August 1968 weighing 15.6 g, an increase of 26% over the juvenal weight.

In contrast, in July the males showed only slight indications of being in breeding condition and no increase in weight. In August, individual males showed varying degrees of cloacal protuberance and while the mean weight increased to 13.1 g, this was only 4.9% above the basic mean.

King et al. (1965:238) found in White-crowned Sparrows that the lipid index in females, though not statistically significant, was greater than that of the males during the breeding season. They attributed this, at least in part, to the lipid content of the ova which were included in the extractions. Morton et al. (1973:85) found in female White-crowneds that "visible" fat stores were maintained through incubation. In my fat index scheme, small or trace amounts of fat were not recorded, but as all breeding females were noted as fat 0 (except one in class 1), the visible fat deposits must have been minimal. Apparently, most of the gain in weight in female goldfinches was from enlargement of the gonads and eggs and an accompanying increase in internal lipids, as suggested by King et al. (1965).

Influence of age on mean weights and measurements.—In September, the newly fledged young in fresh plumage became an important factor in the samples; the adults (including SY birds), not yet molted, were attending them. In Fig. 4, the measurements and weights from September are presented for the various age and sex groups. The HY birds showed a significantly longer mean wing chord than the SY males and the adult females, which influenced the results in Fig. 2. A less important, but nearly identical relation existed in the tail measurements. In the weights, however, only the HY females had a significantly lower mean weight than the other groups.

In considering the ratio of wing chord to weight, the HY males had a longer wing but lower weight than the SY males which had the shortest wing but heaviest weight of males. In females, the HY birds had a longer wing but a lower weight than the adults, but both ages showed mean wing chords well below the means of most of the male groups. It is apparent that age, sex, and feather conditions are variables influencing the size/weight ratio of a bird.

Effects of date and hour of capture on mean weights.—Panel A in Fig. 5 compares the weights of both sexes on individual weekends of February and March 1970. On 15–16 February, a layer of ice covered the landscape, temperatures were below normal, and an exceptionally high number of birds was captured. Also, the 1970 weights peaked: the mean weight of males (17.0 g) was 35.6% above the basic mean while the female mean weight (16.6 g) was 34.4% above their basic mean. Although the first 3 weekends showed mean weights above the February mean in Fig. 1, the final weekend showed a statistically significant drop in weight in both sexes. In March, as temperature began to rise, the mean weights tended to drop but with some adjustments for immediate weather conditions which will be detailed later. There were significant changes. upward and downward, in mean weights of both sexes. The date of capture had an effect on the total sample.

In Panel B of Fig. 5, the male captures were divided into hourly periods and mean weights calculated for these. In February 1970, the earlier means were significantly lower than those of the late hours and the importance of the hour of capture is clear. In March, however, the only significant difference noted was between 07:00 and 11:00, but the highest hourly mean weight for March, recorded at 11:00, was significantly lower than many of the February hourly means. Then, when the first mean of the day (14.9 g) was compared with the last mean (17.7 g), February weights showed an increase of 18.8%. However, in March, these weights (14.2, 15.0 g) indicated the gain was only 5.6%. As the weights in March did not tend to increase throughout the day and a smaller percentage increase was recorded, it seems possible this is a clue to the system by which weight is lost in the late winter. Also, the hourly sample sizes in-

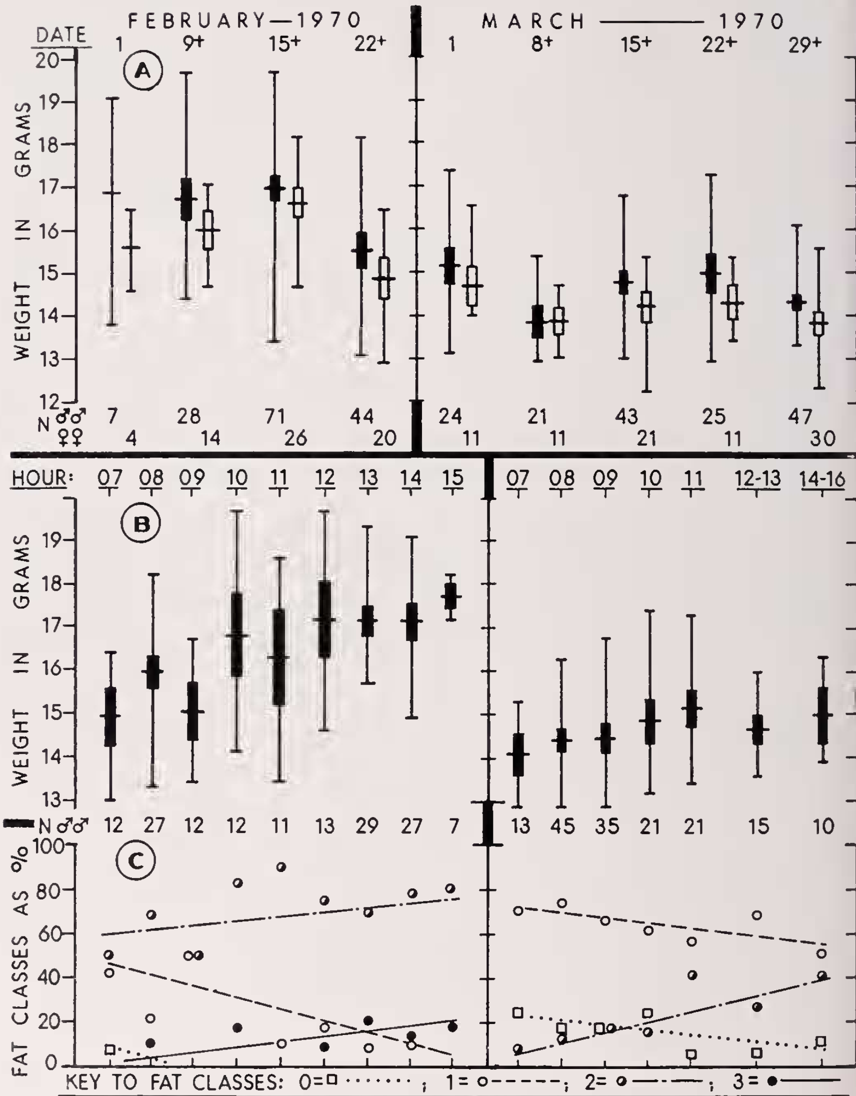

FIG. 5. Weights of samples from February and March 1970. A: samples from individual weekends, "+" following date indicates two days combined. B: samples of males only, weights from each month arranged by hour of capture. C: fat classes as a percentage of total sample for that hour and regression line calculated from percentages for each fat class. Conventions as in Fig. 1.

dicated high feeding activity extended into the afternoons in February, but less so in March. Similar comparisons of female weights indicate similar patterns would have resulted.

The following example demonstrates just how important the hour of capture can be when samples are compared. When I tested January samples, 34 males from 1971 had a mean weight of 14.5 g (S.E. = 0.16) while 33 males from 1972 had a mean of 15.2 g (S.E. = 0.16). Although significant, this difference was related directly to the hour of capture: over half the 1971 birds were taken before 10:00, but only one was taken this early in 1972. Odum (1949) eliminated the weights of birds captured before 10:00 to minimize the "daily rhythm factor," and thus made weights of banded birds comparable with those of collected birds taken only after noon.

The relation of hourly mean body weights to visible fat deposits.—Connell et al. (1960), King et al. (1965), and others found that increases in body weight can be directly attributed to increases in lipids in the body. Mueller and Berger (1966) and West and Peyton (1972) showed that higher weights were correlated with increases in visible fat deposits (classes). I tested to see if there was a relationship between the hourly mean weights and fat classes. In Panel C of Fig. 5, using the samples from Panel B, those males representing each fat class were converted to and charted as a percentage of the total hourly sample. For example: in February at 07:00 there were: 1 bird (8%) in class 0, 5 birds (42%) in class 1, 6 birds (50%) in class 2, but none in class 3. From the percentages a simple linear regression was computed. In February, class 1 birds were a high percentage of the sample in earlier hours, but diminished later in the day. Class 2 birds were a high percentage throughout the day, but the regression line indicated a gradual increase. Similarly, class 3 birds gradually increased throughout the day, but were a small fraction (20%) of the samples even at the highest point. Therefore, as the hourly weight increased, diurnal fat deposits were added and fat classes moved upward to higher classes related to the hourly mean weight.

In March, hourly mean weights and fat classes were lower. Only one bird was class 0 in February, but in March this group was a notable percent of the sample, but gradually decreased through the day. Class 1 birds also diminished in percentage, but were over 50% of the samples throughout the day. While class 2 birds increased in percentage, they were not the major fraction they were in February and class 3 birds were not recorded in March. (Of all my records of fat classes, class 3 was recorded regularly in February only and rarely in January or March.) The net results were consistent with the February findings, even though the fat

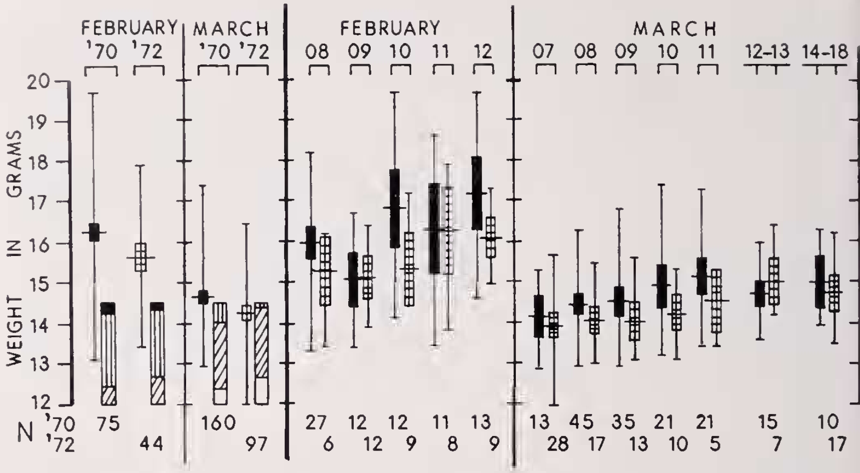

FIG. 6. Comparison of male weights from February and March of 1970 and 1972. First 2 panels present weights from samples for the months from each year and fat classes as percentage of the sample. Conventions as in Fig. 1, but filled rectangles are males from 1970 while cross-hatched rectangles are males from 1972. Key to fat classes: open rectangles = fat class 0; diagonal hatching = class 1; vertical hatching = class 2: filled rectangles = class 3. Last 2 panels present weights of males by hour of capture during month as listed at top.

classes were lower. Progressively into summer, fat classes continued to decrease. I detected no evidence of pre-migratory fat buildup.

Effects of handling on weights.—Various studies produced different results on this subject. While Mueller and Berger (1966) found a slight decrease in weight for birds recaptured on the same day, Helms and Drury (1960) found that these birds followed the normal diurnal trend of variation when averaged. When I examined my records, I found that most birds recaptured within 1 to 3 hours showed small weight losses, but after 6 to 8 hours these and other birds showed gains of 1 to 9%. However, because none of the birds recaptured in February or March had gained weight in line with the averages shown in Figure 5-B, I excluded all but the weights from initial captures for the day.

When I examined the records of birds captured on 2 consecutive days and considered the hours of capture, I found no consistent pattern. However, as these captures represented only about 1% of the weights and were scattered throughout the year, they were included.

Variation between years.—A study of male weights from February and March of both 1970 and 1972 was undertaken. However, in February 1972, the birds were taken only from 08:00 through 12:00, so it was necessary to extract the birds captured in these hours in February 1970. In Fig. 6, the first panel compares the samples of males from these hours of February and the males from all hours of March for these years. In both months, the 1970 mean weights were significantly higher than the 1972 means.

In the same panel, the percentages of birds in the fat classes within each sample are charted. In February, the percentage of class 3 birds was greater while class 1 birds was smaller in 1970 than in 1972. Similarly, in March, the percentage of class 2 was greater while class 0 was smaller in 1970 than in 1972.

In the 2 final panels of Fig. 6, the weights of comparable hourly samples were studied. In February, the 1972 samples showed no significant changes, but in 1970 both the 10:00 and 12:00 samples were significantly above the 09:00 weights. Although not significant, the 3 even-numbered hours showed noticeably higher means in 1970 than in 1972. When I examined the male weights as weekend samples (not shown), the February 1972 peak mean weight (15.9 g) was reached on the first weekend, compared with 17.0 g on the third weekend of 1970 (see Fig. 5). Birds captured on the last 3 weekends of 1972 had mean weights below the lowest mean of the 1970 weekends. Weather conditions were not appreciably different in these years, so no explanation for these variations can be offered.

In March, the 1970 weights peaked at 11:00 (Fig. 6). While this was significantly above only the 07:00 weights of 1970, it was significantly higher than the 1972 hours of 07:00, 08:00, and 09:00. Again, no explanation can be offered. Smaller samples indicated similar trends for females in each period.

When April samples of males from 1970, 1971. and 1972 were compared (Fig. 7), no significant differences among the years were found. However, weekend samples from each year showed a variation in pattern. Consistent with the monthly trend in Fig. 1, a gradual downward slope in mean weights occurred in 1970 and 1971. However, in 1972 the birds were captured throughout the day only on 9 and 23 April. For unknown reasons, 60% of the birds were taken before 10:00 on 3 April, yielding an abnormally low mean weight. The mean was high and the sample small on 18 April as we did not work that morning. The need for comparing similar hours of capture (and banding efforts) is obvious.

The females from 1971 weekends were significantly lighter in weight than the males. Both sexes showed significantly higher mean weights on the first weekend and significantly lower means on the last weekend. Other female samples were too small for analysis. The exact effect of the prenuptial molt was not determined.

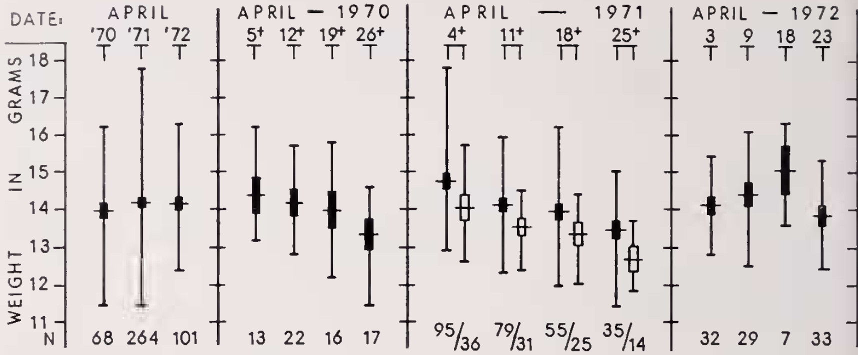

FIG. 7. Comparison of weights from each April of 3 years. Conventions as in Fig. 1. First panel presents total sample of males for each year. Remaining panels present samples by individual weekends, "+" following date indicates 2 days combined.

Variations between consecutive weekends.—With sizeable samples available, the male weights were studied in hourly periods on the first 3 weekends of April 1971 (Fig. 8). Within each weekend, the hourly changes were not significant, but each weekend showed a different pattern and significant changes in certain mean weights. On 4–5 April, the mean increased through the morning hours, typical of the changes seen thus far. On 11 April, mean weights started to rise, but then dropped, so that at 10:00 the mean was significantly lower than at the same hour on the prior weekend. On 18 April, the number of birds captured in the first 3 hours dropped drastically, but the mean weight of these few birds had not changed from the previous weekends. However, at both 10:00 and 11:00, the weights had decreased and both were significantly lower than they had been on 4–5 April. When considered collectively, these weekends indicate a general downward trend in April mean weights as had been noted in Fig. 7, but examined individually, they provide details on the gradual loss of weight.

Variations between successive days.—It is rare that birds are captured on 2 successive days in numbers large enough to permit analysis, but in 1971 I captured 55 males and 18 females on 4 April and 40 males and 18 females on 5 April (Fig. 9). By the test used, the mean weight of each sex did not increase significantly, although on the second day, the males had gained 2.7% and the females 3.6% which is counter to the downward trend noted in Fig. 7. When male weights were plotted by the hour for each day, the changes were not significant, but a comparison of the first and last mean indicated a gain of 5 to 6% occurred through each morning.

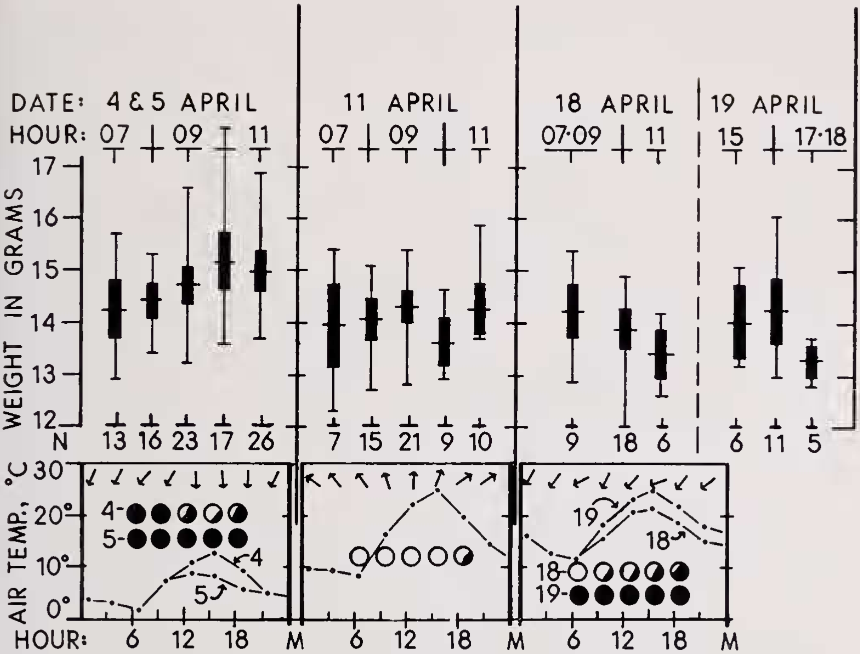

Fig. 8. Weights of males from first 3 weekends of April 1971 presented by hour of capture on specific date. Conventions as in Fig. 1. Lower panels summarize weather observations at three-hour intervals on date of capture. Arrows indicate wind direction on weekend, north at top of figure. Circles indicate sky conditions: filled circles = fully overcast skies; open circles = no clouds; partially filled circles = % of clouds to clear sky. Temperatures presented by connected dots. Number inside panel is date of weather if different patterns occurred.

which is equal to the gain in March (Fig. 5-B) when temperatures were much lower. Also, the mean weight for each hour was consistently higher on the second day. If all conditions were equal, the Laws of Chance (Moroney 1951) imply this could happen only once in 32 cases (P = 0.04). But, were all conditions equal? I suggest that weather had effected this result.

Effects of weather on mean weights.—It has been demonstrated that mean weights are inversely correlated with ambient temperatures on a long-range basis (see above). My findings suggest that birds are also sensitive to immediate changes in weather conditions, possibly to the availability of solar radiation and to wind velocity, and that they respond immediately with short-lived changes in mean weight.

With sex, age, and hour of capture described, I examined the weights

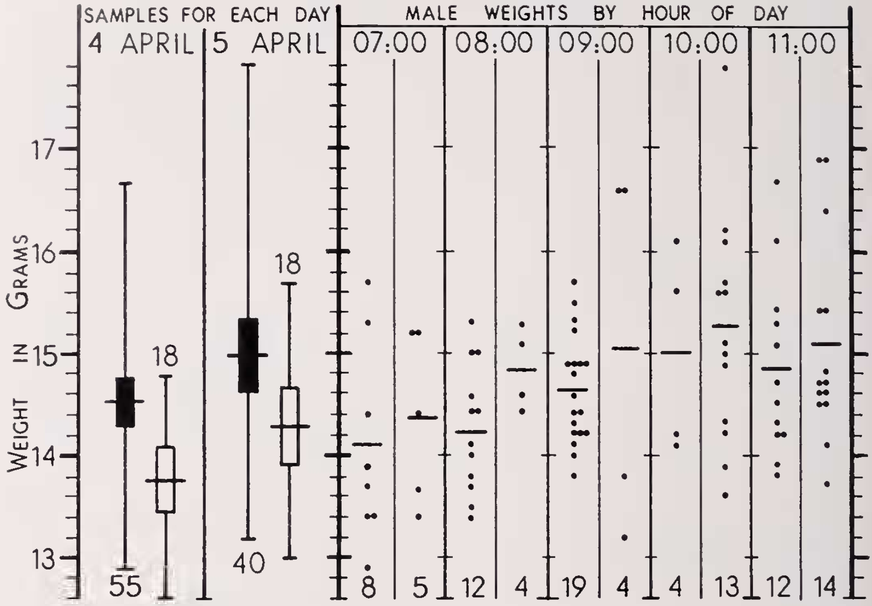

FIG. 9. Body weights from 4 and 5 April 1971. First panel compares sample of each sex from individual days. Final panel presents weights of individual males (dots) by hour of capture with simple mean (horizontal line) for each day, 4 April to left and 5 April to right. Numbers at bottom are sample sizes. Conventions as in Fig. 1.

of April 1971 for effects of changes in weather (summarized in Fig. 8). As mean temperatures for each weekend (7°, 14°, and 17°) were increasing, mean weights were decreasing (Fig. 7). However, slight variations in weight could not be related to temperature changes alone. On 4–5 April, barometric pressure and wind direction were unchanged as mean temperature dropped a mere 2° on 5 April. However, mean wind velocity increased from 15 km/hr on 4 April to 31 km/hr on 5 April and this, coupled with a lack of sunshine, may have effected at least part of the increased weights shown in Fig. 9.

On 11 April, with higher temperatures, less wind, and clear skies, the birds initially came in fair numbers. then feeding activities subsided (Fig. 8). With similar weather on the following day, the birds ignored the food in our traps. A week later, on 18 April, the birds came in small numbers as the temperatures were high and the skies mostly clear. But on 19 April, (we could not work the traps in the morning) the temperatures were even higher, yet the birds came in fair numbers in the late hours, possibly ingesting more food as a reaction to stronger NNE winds and overcast skies.

Similar reactions to the lack of solar radiation were found in March 1970. The first 2 weekends (mean 8°C) were about 5°C above normal. On 1 March, with no sunshine available, the weights were high (Fig. 5); whereas they were significantly lower on 8 March with 90% available sunshine. On the next 2 weekends, we had fog and overcast skies each day. On 15–16 March, mean temperatures dropped to –4°C and –6°C with winds NNW at 15 to 25 km/hr and light snow, so all species were actively feeding and goldfinch weights were again high. On 22–23 March, however, mean temperature (4°C) was higher, winds were slower at 10 to 15 km/hr, but weights were still high. It is impossible to say that sky conditions were responsible for all of the increase, but higher temperatures did not produce a drop in weight that would be expected.

Feeding activities at this station have been noted, when temperatures remain unchanged at lower levels, to be inversely proportional to the availability of sunshine (solar radiation). Apparently, small birds are sensitive to solar radiation and wind velocity and direction, and these effect minor, short-term fluctuations in weights.

Relation of wing chord to weight variations.—Most authors (Connell et al. 1960, Mascher 1966, Rogers and Odum 1964) have used the wing chord or flattened wing measurement as an indicator of size of the bird's framework and some have found no differences in the fat-free weight due to sex or age if the wing measurements were the same. However, Nolan and Mumford (1965), working with migrating warblers of TV tower kills, stated, "... coefficients of correlation of wing length and total weight emphasize the lack of constancy in the relation when weight includes fat," and added, "Significant differences existed in average measurements and weights; in some instances the differences were related to both age and sex, in some to only one of these variables."

With this in mind, I separated the goldfinches by sex, age, and wing length and determined the mean body weight of these at various time periods, some of which are presented in Fig. 10. In the top panel, September data are presented first. With fresh plumage the HY males were rather evenly distributed through the range of wing sizes, and the mean weights increased in correlated, orderly steps. All samples tended to show this, but few samples showed a relationship as well coordinated as this. In October, the individual weights of HY birds varied considerably, some young were self-dependent and late hatched parent-dependent young were also present, and the wing/weight relation was obscured. A few adult males, now molting, were about 2 g heavier than adult females, not yet

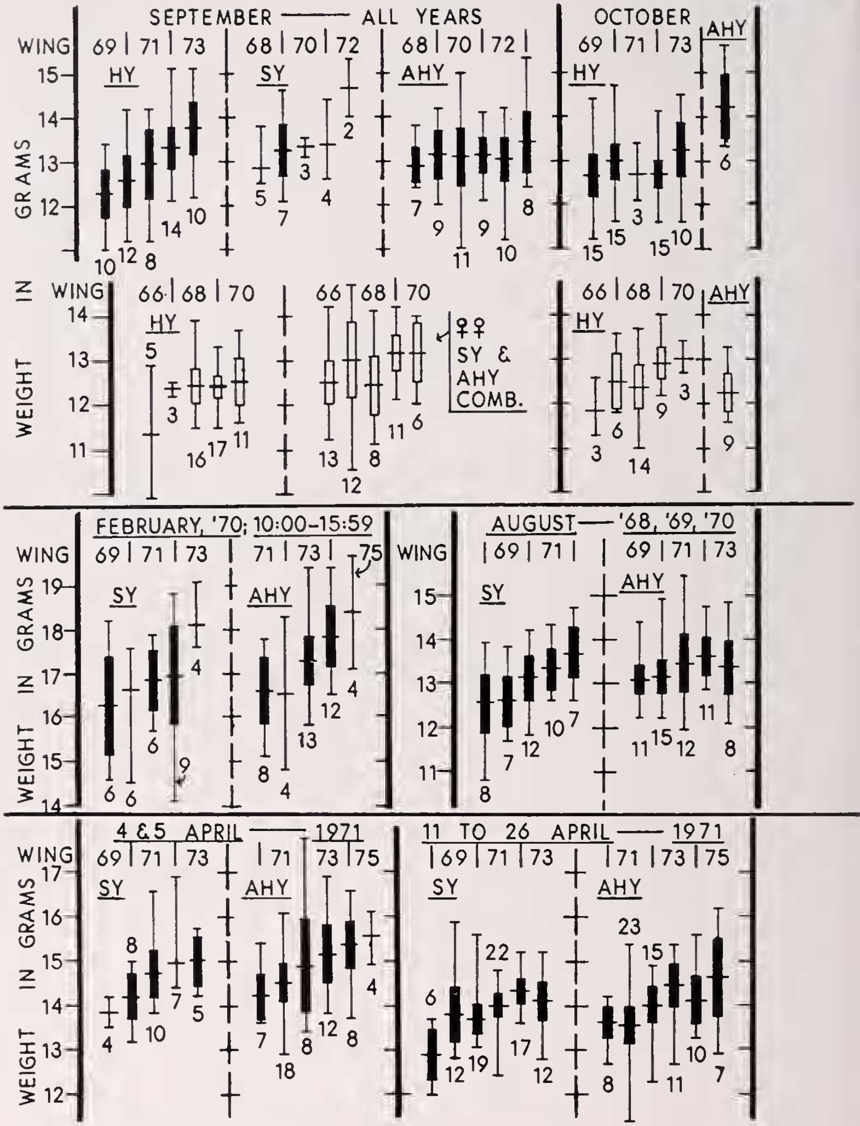

FIG. 10. Selected examples of wing chord/weight relations. Samples from various dates or time periods were divided by wing chord lengths, then weights were calculated for each sample. Conventions as in Fig. 1.

molting, while HY males were only about 0.5 g heavier than HY females. While females tended to follow the correlated pattern, because of smaller samples, disproportionate importance was given to the individual bird, breeding condition, molt, and/or feather wear.

When the February SY males were compared to the September HY males, each group by wing size was noted to have added essentially the same amount of weight (about 4 g). By August, the SY males were about the same weight as they had been the prior September; however, the wing measurements had been reduced about 1.5 mm. (In Fig. 4, by comparing HY and SY birds in September, the loss was determined as 1.7 mm for the year.) In comparing age groups, the February males showed a noticeable difference. Although the weights were fairly evenly matched, the AHY birds had measurements about 2 mm longer than those of the SY birds (note the scales on wings are not identical). By April, the difference had narrowed to about 1.4 mm. In Fig. 4, September wing chords were only about 1 mm longer on the AHY birds. Apparently, the factors of feather wear relative to age, sex, nesting, and molt may have some slight influence on the wing/weight relationship, and the rate of wear may not be constant throughout the year in the various groups.

In the lower panels of Fig. 10, males from 4–5 April 1971 produced similar patterns in both age groups, but birds taken from the following 3 weekends of April 1971 failed to show this relationship. It seems temporal consolidation of the samples is important to this study. Also, hour of capture can play upon the results. Note that the February 1970 samples were restricted to the hours after 10:00; when I included weights from earlier hours, the relationship was obscured.

SUMMARY

During a general banding program conducted on weekends for 5 years at the Cincinnati Nature Center, weights and wing chord measurements of American Goldfinches were recorded. From this, 1448 weights of 978 males and 756 weights of 538 females were obtained, treated as separate populations, and divided into age-related samples representing various time and biological periods. The means ± 2 S.E. were used to make simple comparisons between seasons, weekends, days, and hourly periods.

A comparison of weights by months showed weights were inversely related to temperature. Evidence of an increase in weight during molt was noted. During the summer, the lowest (basic) mean weights were attained (12.5 g for males and 12.4 g for females), and both sexes gained about 4% during the day. During the breeding season the females gained 7.3% and males gained 4.9% above the basic mean weight. In February, the male mean weight was 35.6% and the female mean was 34.4% above the basic mean weight. At this time males gained 19% during the day, but in March they gained only 5.5% in a day. Fat classes (deposits) were shown to change paralleling the hourly changes in mean weight.

The date of capture and mean weights were not correlated. The hour of capture produced significantly lower mean weights in the earlier hours of the colder months, but not in the warmer months. The handling of birds appeared to reduce the gain in diurnal weight during February and March. Variations in mean weights between various years in selected months were found to be related to hour of capture or weather in some cases.

The effects of weather were demonstrated. Changes in solar radiation, wind direction and velocity, and immediate changes in temperature seemed to affect weight and feeding activities in hourly and daily periods.

The ratio of total weight to wing chord was shown to vary with season, sex, and age. In both sexes, the newly fledged young had significantly longer wing chords than most adults of their sex.

ACKNOWLEDGMENTS

I am especially indebted to B. Franklin McCamey who introduced me to the principles of banding and inspired a serious approach to the project, then assisted and advised with many technical problems. Through the years, Richard Durrell and the Trustees of the Cincinnati Nature Center encouraged this research and made it possible by providing working space and special privileges in the use of the Nature Center land areas, for which I am grateful. The friendly cooperation of the staff and members of the Nature Center for their many favors and courtesies is gratefully acknowledged, especially their attentiveness to providing feed for our traps throughout the project.

Mary H. Clench contributed unlimited and extremely valuable assistance which made this paper possible, and I am indebted to her. DeVere E. Burt and Chandler S. Robbins provided suggestions on the figures. Jack L. Gottschang and the staff of the University of Cincinnati provided access to the University's computer and advised in this work. My wife, Virginia K. Wiseman, provided cooperation and support at every step in many ways to make this paper possible. Jay M. Sheppard introduced me to computer manipulation of the data. Jean K. Cassell provided much needed typing assistance. Funds received in 1974 through the Margaret Morse Nice Award from the Wilson Society provided partial assistance.

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CINCINNATI MUSEUM OF NATURAL HISTORY, 1720 GILBERT AVENUE, CINCINNATI, OH 45202. ACCEPTED 26 DEC. 1974.